Middle St. Croix Watershed Management Organization 2017 Water Monitoring Summary

Prepared For:

Prepared by:

Washington Conservation District

This Page Intentionally Left Blank.

ACKNOWLEDGEMENTS

Multiple agencies and individuals were directly involved in many aspects of this project, such as data collection, data analysis, as well as technical and administrative assistance.

Middle St. Croix WMO (MSCWMO) Board of Managers
Annie Perkins
Patrick McGann
John Fellegy
Brian Zeller, Chair
Joe Paiement, Vice Chair
Tom McCarthy
Mike Runk
Nancy Anderson, Secretary
Doug Menikeim
Dan Kyllo, Treasurer

Washington Conservation District
Mike Isensee, MSCWMO Administrator

Metropolitan Council
Brian Johnson
Mallory Vanous
Mike Moger
Sarah Voth

Minnesota Department of Natural Resources (MN DNR)
Sandy Fecht

The WCD would also like to thank the volunteers and landowners who assist with data collection and access to our monitoring location

TABLE OF CONTENTS

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Anoxic	Lacking oxygen
BCWD	Brown's Creek Watershed District
Benthic	The area nearest lake bed
Biweekly	Every two weeks
BMP	Best Management Practice
cf	cubic feet
cfs	cubic feet per second
Chl-α	Chlorophyll-α
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
IESF	Iron Enhanced Sand Filter
Littoral zone	The area of a body of water where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow
MCES	Metropolitan Council Environmental Services
mg/L	milligram per liter
MN DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MSCWMO	Middle St. Croix Watershed Management Organization
NCHFE	North Central Hardwood Forest Ecoregion
OHW	Ordinary High Water level
SOP	Standard Operating Procedure
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSMP	Trout Stream Mitigation Project
TSS	Total Suspended Solids
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
WCD	Washington Conservation District

EXECUTIVE SUMMARY

This report focuses on the summary and comparison of lake and stream water quality data collected by the Washington Conservation District (WCD) in 2017 as well as previous years. In 2017 the Middle St. Croix Watershed Management Organization (MSCWMO) monitored both water quality and water surface elevation on McKusick Lake and Lily Lake, flow and water quality at the Greeley Street Inlet to Lily Lake, Perro Creek at the Perro Pond Outlet, and Perro Creek at the Diversion Structure, water quality at Perro Creek at 6^{th} Street, and flow at Perro Pond Outlet Direct to the Saint Croix. The purpose of this monitoring is to assess and document current water quality conditions of the lakes and streams, as well as continuing a long-term monitoring program that will enable the MSCWMO to identify trends associated with best management practice (BMP) implementation and land use changes in the watershed.

Lake Monitoring

Lily Lake was classified as eutrophic (Table 2) and received a C+ grade in 2017 (Table 3). Lily Lake was within the North Central Hardwood Forest Ecoregion (NCHFE) range for chlorophyll-α (chl-α), total phosphorous (TP), total Kjeldahl nitrogen (TKN) and Secchi disk transparency readings for the 2017 monitoring season. Three samples collected exceeded the Minnesota Pollution Control Agency's (MPCA) threshold for TP, and six samples collected exceeded the MPCA threshold for chl-α corrected for pheophytin. Six of the Secchi disk transparency readings exceeded the MPCA threshold (APPENDIX A).

In 2017 McKusick Lake was classified as eutrophic (Table 2) and received a grade of C+ (Table 3). McKusick Lake was above the NCHFE range for TP and within the NCHFE range for chl-α, TKN, and Secchi disk transparency. Three water quality samples exceeded the MPCA shallow lake threshold for TP, and two samples exceeded the MPCA threshold for chl-α corrected for pheophytin. Two Secchi disk transparency measurements exceeded the MPCA shallow lake threshold (APPENDIX A).

The Brown's Creek Diversion Structure site, which exports to McKusick Lake, showed a decrease in discharge in 2017 to 39,625,672 cubic feet (cf) from 70,780,581 cf in 2016. The phosphorus load decreased from 1,574 lbs. in 2016 to 784 lbs. in 2017. TSS also showed a decreased export from the Brown's Creek Diversion Structure to McKusick Lake, from 1,533,496 lbs. in 2016 to 596,382 lbs. in 2017 (Table 4 and Table 5). The erosion occurring from a head cut on the South Branch of Brown's Creek, upstream of the diversion structure, also appears to be contributing high concentrations of heavy metals. Although fewer and less severe than previous years, exceedances of copper and lead continue to be an issue.

Stream and Storm Monitoring

In 2014 the MSCWMO discontinued monitoring of Brick Pond. The MSCWMO instead focused on problem investigation monitoring strategies for Lily Lake and Brick Pond that began in 2015. This approach will enable the MSCWMO to better determine sources of pollutants and more effectively implement management strategies and practices to address those sources. In 2017 monitoring focused on the Greeley Street catchment of Lily Lake. Results in 2017 were similar to results in prior years (Figure 8 and Figure 9). Greeley Street catchment base flow grab samples had low concentrations of TP and TSS (Table 7 and Table 8). Storm event grab sample results continued to be much higher than base samples. These results confirm previous results that the majority of loading to Lily Lake occurs during storm events.

The MSCWMO continued monitoring Perro Creek to identify where the greatest contribution of pollutants to the Saint Croix River was occurring. This investigatory monitoring started in 2016. Three sites were monitored for TSS, TKN, and TP; Perro Creek at the Perro Pond Outlet, Perro Pond Outlet Direct to the St. Croix, and Perro Creek at the Diversion Structure. Three sites were also monitored for *E. coli*; Perro Creek at the Perro Pond Outlet, Perro Creek at 6th Street, and Perro Creek at the Diversion Structure. Results from samples collected in 2016 at Perro Creek at the Perro Pond Outlet and Perro Pond Outlet Direct to the St. Croix were similar; as such, no samples were collected at Perro Pond Outlet Direct to the St. Croix in 2017.

In 2017 two sites along Perro Creek were monitored for TSS, TKN, TP, and *E. coli*; Perro Creek at the Perro Pond Outlet and Perro Creek at the Diversion Structure. *E. coli* was also collected at Perro Creek at 6th Street. Perro Creek at the Perro Pond Outlet had low sample results compared to Perro Creek at the Diversion Structure, and as compared to 2016 results. Perro Creek at the Diversion Structure also had sample results lower than 2016. The *E. coli* results for Perro Creek at the Perro Pond Outlet were lower than in 2016. Perro Creek at 6th Street had higher levels of *E. coli* than Perro Creek at the Diversion Structure for half of the samples taken despite being upstream (Table 11). Perro Creek at 6th Street is exceeding MPCA impairment standards from June-September (Table 12).

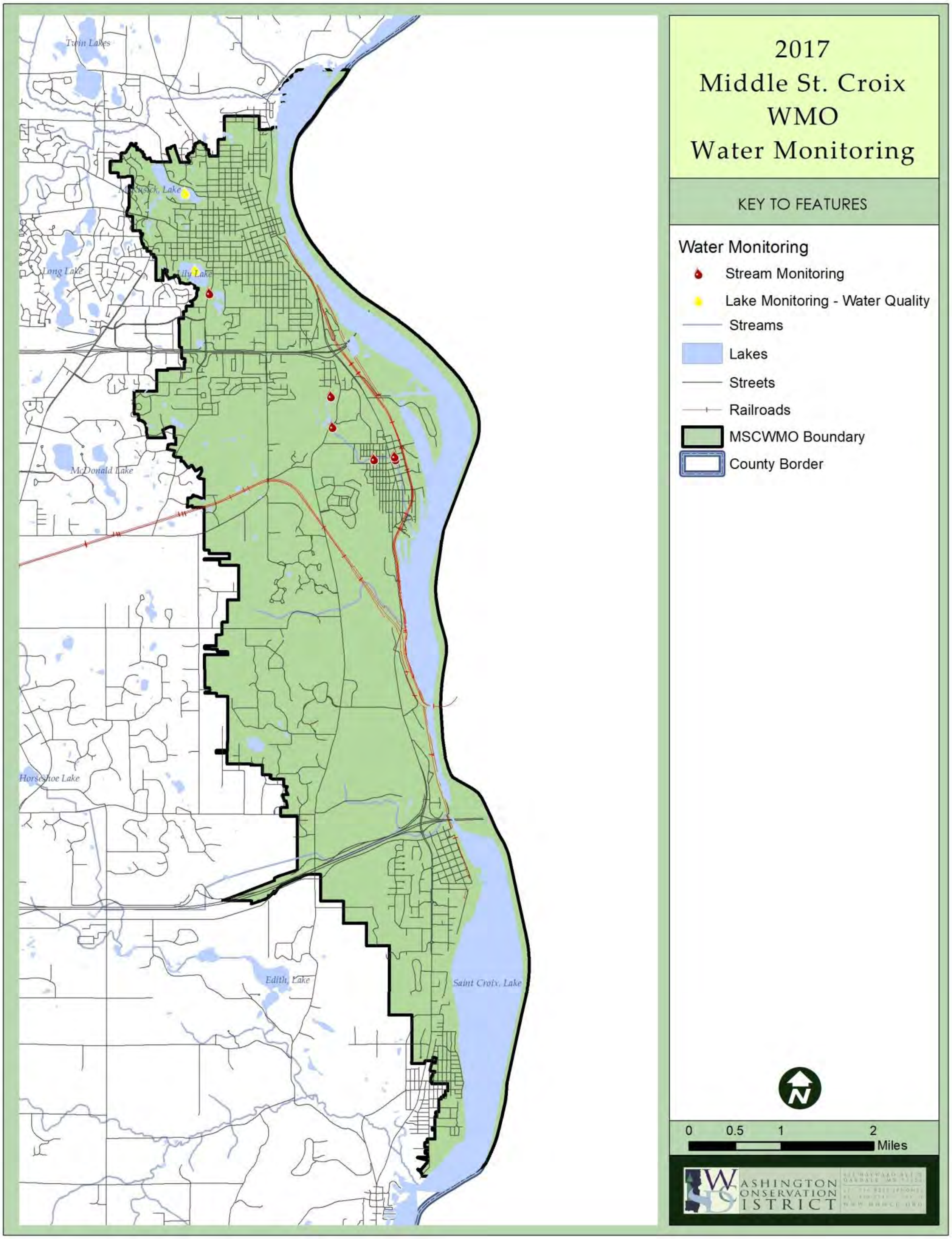


Figure 1. MSCWMO 2017 Water Monitoring Locations

LAKE MONITORING

A. METHODS, RESULTS AND DISCUSSION

In 2017 water quality data was collected biweekly on Lily Lake and McKusick Lake, over seven consecutive months (April–October) by the Washington Conservation District. Measurements obtained during the summer sampling season (June–September) are averaged for a comparison of individual lake dynamics from year to year between lakes within the watershed, to the average NCHFE ranges, and to the Minnesota Pollution Control Agency's (MPCA) impairment standards. Lake grades are based on the averages of samples collected May–September. Average values for all parameters, as well as typical ranges for lakes in the NCHFE, are presented in APPENDIX A and Figure 4 through Figure 7 which show the current and historic summer averages for each parameter. Water quality samples were collected by the WCD with a two-meter (6.56 feet) integrated surface water column sampler. A full description of WCD Standard Operating Procedures is available on the Washington Conservation District website at http://www.mnwcd.org/water-quality-water-monitoring/. The Metropolitan Council Environmental Services (MCES) Laboratory analyzed the surface water samples for TP, chl-α, and TKN on all MSCWMO lakes.

Total phosphorus is analyzed as it is a major nutrient involved in the eutrophication of lakes and is generally associated with the growth of aquatic plants and/or algal blooms. Common sources of phosphorus include runoff from agricultural fields, livestock areas, urban areas, lakeshore lawns, and improperly operating septic systems. With most lakes in this region, phosphorus is the least available nutrient; therefore, its abundance, or scarcity, controls the extent of algal growth. Algal growth, in turn, affects the clarity, or transparency, and ability of light to penetrate the water. The typical range of the NCHFE for TP is 0.023 – 0.050 mg/L. The MPCA sets lake eutrophication standards for aquatic recreation use. The standard for TP is 0.040 mg/L for deep lakes and 0.060 mg/L for shallow lakes. In general, shallow lakes are defined as less than 15 feet deep, with greater than 80% littoral area, and less than 10 acres. The 2017 summer average of TP values of MSCWMO lakes can be found in Figure 4.

Chlorophyll-α is measured as it is the photosynthetic component found in algae and aquatic plants and is an indicator of algal productivity. The typical range of the NCHFE for chl-α is 5 –

22 μg/L. The MPCA standard for pheophytin-corrected chl-α is 14 μg/L for deep lakes and 20 μg/L for shallow lakes. The 2017 summer average chl-α concentrations of MSCWMO lakes can be found in Figure 5.

TKN, the sum of organic nitrogen and ammonia was analyzed in MSCWMO lakes. TKN is analyzed as it can increase the rate of lake eutrophication. The NCHFE typical range for TKN is 0.60-1.20 mg/L. There is no impairment standard for TKN set by the MPCA because TP is the nutrient used in their assessments. The 2017 summer average TKN concentrations of MSCWMO lakes can be found in Figure 6.

Table 1. North Central Hardwood Forest Ecoregion Values and Average 2017 Parameters

2017 MSCWMO Lakes Summer Averages (June-September)					
Lake/Units	**Total Phosphorus (mg/L)**	**Chlorophyll-*a* (μg/L)**	**Total Kjeldahl Nitrogen (mg/L)**	**Secchi Disk (meters)**	**Deep Or Shallow**
Eco-Region Value	*0.023-0.050*	*5.0-22.0*	*0.60-1.20*	*1.5-3.2*	
MPCA Deep Lake Impairment Threshold	*0.040*	*14.0*		*1.40*	
MPCA Shallow Lake Impairment Threshold	*0.060*	*20.0*		*1.00*	
Lily	0.037	18.5	1.00	1.52	Deep
McKusick	0.056	10.8	0.89	1.59	Shallow

Field measurements are recorded while collecting lake samples, including Secchi disk transparency. The measurement of light penetration using a Secchi disk gives a simple measure of water transparency, or clarity. A reduction in water transparency is typically the result of turbidity composed of suspended sediments, organic matter and/or phytoplankton (algae). Typical ranges for transparency in the NCHFE are between 1.5 – 3.2 meters. The MPCA standard for Secchi disk transparency is 1.4 meters for deep lakes and 1.0 meter for shallow lakes.

User perception and physical/recreational suitability of lakes were recorded, along with temperature and dissolved oxygen (DO) profile measurements taken by the WCD during each sampling event. Profiles are recorded at one meter increments from the water surface to the lake bottom. The data show the extent of summer stratification and are useful in identifying the development of a thermocline (the layer of water in which the temperature rapidly declines). As a lake stratifies, the water column becomes more stable and mixing is less likely to occur. If mixing occurs during the growing season, nutrients from the lake bottom become available and can result in increased algal production. Lake DO profile data is useful in determining excessive production (algae/plants) in a lake. Increased production creates more DO, for a time, but as plants and algae die off and decay, they change from producers of DO into consumers through the process of decomposition. Low DO conditions may stress fish populations and under anoxic conditions nutrients may be released from the sediment. Data collected from the rankings and profiles are contained in a database at the WCD, and can be obtained by request, as well as on the MPCA website at http://cf.pca.state.mn.us/water/watershedweb/wdip/index.cfm.

The Carlson Trophic State Index (TSI) is used to quantify the relationship between water quality data and trophic status (Table 2). Many water quality scientists classify lakes according to their trophic state. The average summer value of chl-α is most often used to determine a lake's trophic state. Additionally, TP and Secchi transparency are used to provide further information on lake dynamics. Oligotrophic lakes, such as lakes common in the northeastern part of Minnesota, have low biological activity as a result of low phosphorus concentrations, low chl-α concentrations, and high Secchi disk transparency readings. Mesotrophic lakes have slightly more biological production, and are characteristic of the majority of the lakes found in the NCHFE of Minnesota. On the other end of the spectrum, lakes with high biological productivity characterized by high phosphorus concentrations, high chl-α concentrations and low Secchi disk transparencies are classified as eutrophic or even hypereutrophic. Lakes classified as eutrophic or hypereutrophic typically receive excess nutrient loading from sources within their watersheds and receive large amounts of runoff from the surrounding drainage area. A percentage of these nutrients, however, can also be attributed to internal loading within the lake itself, which is typical of shallow, sediment-rich lakes.

Table 2. Trophic State Index and Ranges

	Trophic State Index	TP (µg/L)	Chl-*a* (µg/L)	Secchi (m)
Oligotrophic	<40	<12	<2.6	>4.0
Mesotrophic	40-50	12 - 24	2.6 - 6.4	4.0 - 2.0
Eutrophic	50-70	24 - 96	6.4 - 56	2.0 – 0.5
Hypereutrophic	>70	>96	>56	<0.5

A lake grading system is also used in this summary, to allow for a better understanding of lake water quality data and to aid in the comparison of lakes. The lake water quality grading system was developed following the 1989 sampling season by Dick Osgood, formerly of the Metropolitan Council. The concept of the lake grading system is a ranking of water quality characteristics by comparing measured values to those of other metro area lakes. The grading system represents percentile ranges for three water quality indicators: the May through September average values of TP, uncorrected trichromatic chl-α, and Secchi disk transparency. These percentiles use ranked data from 119 lakes sampled from 1980-1988 and are shown in Table 3. This method has since been replicated and the grading system has been verified with more recent data. The variables used in the grading system strongly correlate to open-water nuisance aspects of a lake (i.e. algal blooms), which can indicate accelerated aging (cultural eutrophication). There is a strong correlation when comparing trophic status to the lake grade. Summaries of all lake results are presented in APPENDIX A.

Table 3. Lake Grade Ranges

Grade	Percentile	TP (µg/L)	Chl-α (µg/L)	SD (m)
A	<10	<23	<10	>3.00
B	30-29	23-31	10-19	2.20-3.00
C	30-69	32-67	20-47	1.20-2.19
D	70-90	68-152	48-77	0.70-1.19
F	>90	>152	>77	<0.70

Water elevation monitoring was conducted on two lakes, McKusick and Lily, from May to October 2017. Lake elevation readings are compared to the lake's Ordinary High Water level (OHW)[1]. Changes in lake water elevation are often attributed to the changes in precipitation. The highest recorded elevations in 2017 for both McKusick Lake and Lily Lake occurred on 5/22/17. Complete lake elevation data for 2017 can be found in Figure 2 and Figure 3. For historical lake elevations, visit the MN DNR Lake Finder webpage at http://www.dnr.state.mn.us/lakefind/index.html.

1. LILY LAKE

In 2017 the WCD staff conducted two-tailed Kendall's Tau statistical analysis on both lakes monitored within MSCWMO to determine trends for TP, Secchi, and chl-α ($p<0.05$). Lily Lake had a statistically significant improving trend for TP and no trend was found for average Secchi disk transparency or chl-α. Lily Lake had an average summertime TP concentration of 0.037 mg/L, the same as 2016, which is below the MPCA lake nutrient impairment threshold for TP (Figure 4). Three of the nine summertime results were greater than the MPCA lake nutrient impairment standard for TP. The 2017 average summertime concentration of chl-α was 18.5 μg/L; lower than the 23.9 μg/L measured in 2016 (Figure 5), with six of the nine water quality results exceeding the MPCA lake standard for chl-α impairment (APPENDIX A). Lily Lake had an average summertime TKN concentration of 1.00 mg/L in 2017; higher than the 0.92 mg/L seen in 2016 (Figure 6). Secchi disk readings were measured in 2017 with a summertime average of 1.52 meters (Figure 7), with six of the nine water quality readings exceeding the MPCA lake standard for Secchi disk transparency impairment (APPENDIX A). Lily Lake received a grade of C+ in 2017; unchanged from 2016. Temperature and DO profiles indicate

---

[1] Minnesota State Statutes defines the ordinary high water level (OHW) as follows: Minnesota Statutes 103G.005 Subd. 14. Ordinary High Water Level. "Ordinary high water level" means the boundary of water basins, watercourses, public waters and public waters wetlands, and: The ordinary high water level is an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial;

1) For watercourses, the ordinary high water level is the elevation of the top of the bank of the channel; and
2) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.
3) For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool.

that Lily Lake exhibited thermal stratification during the summer months with the thermocline around 4 meters; therefore the lake was less likely to completely mix throughout the summer. Lily Lake was below the OHW for two elevation readings, falling to its lowest recorded level on 9/25/17 with an elevation of 845.27 ft. The elevation was above the OHW for most of the monitoring season, reaching its highest recorded level on 5/22/17 with a level of 846.60 ft. (Figure 2). A summary of all lake results is presented in APPENDIX A.

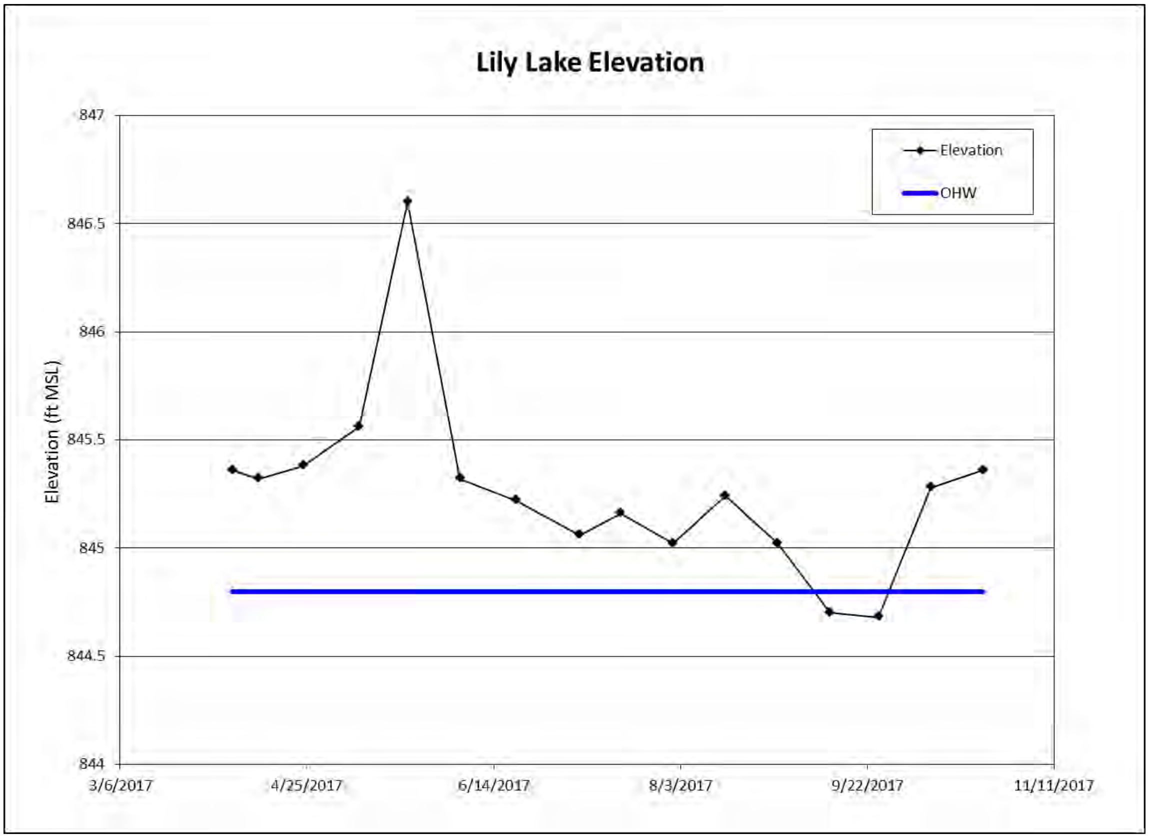


Figure 2. Lily Lake 2017 Elevations

2. MCKUSICK LAKE

A two-tailed Kendall's Tau analysis showed that McKusick Lake has statistically significant ($p<0.05$) improving trends for TP and Secchi transparency, and no trend is present for chl-α. The McKusick Lake summertime average TP concentration in 2017 was 0.056 mg/L; lower than the 0.059 mg/L observed in 2016 (Figure 4), with three of the nine summertime water quality samples collected exceeding the MPCA TP impairment standard for shallow lakes (APPENDIX A). McKusick Lake had a summertime average chl-α concentration of 10.8 μg/L; lower than the chl-α average of 19.0 µg/L from 2016 (Figure 5). Of the nine summertime samples collected in 2017, two exceeded the MPCA shallow lakes standard for chl-α. The average summertime TKN concentration for 2017 was 0.89 mg/L; slightly higher from the 0.88 mg/L measured in 2016 (Figure 6). The 2017 summertime average water transparency measured by Secchi disk was 1.59 meters (Figure 7). All but two of the Secchi disk readings in 2017 were better than the MPCA lake impairment standard. The overall water quality of McKusick Lake is comparable to the previous year, receiving a grade of C+ for 2017. No change in grade was seen from 2016. Temperature and DO profiles indicate that McKusick Lake exhibited thermal stratification during the summer months in the deepest portion of the lake with the thermocline around 3 meters. A majority of McKusick Lake is very shallow and does not stratify, and therefore is likely to have mixed throughout the summer. The elevation of McKusick Lake remained above the OHW for the entire monitoring season, reaching its highest recorded level on 5/22/17 with a level of 855.23 ft. and falling to its lowest recorded level on 8/29/17 with an elevation of 854.32 ft. (Figure 3). A summary of all lake results is presented in APPENDIX A.

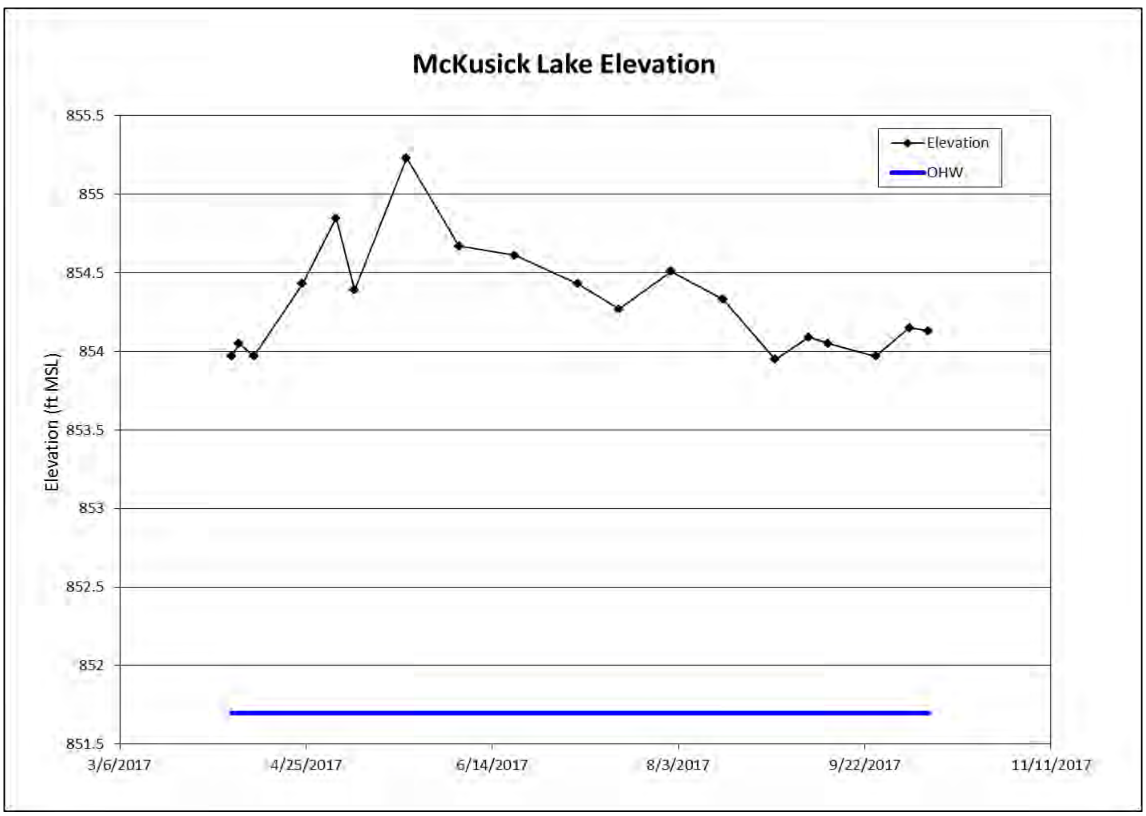


Figure 3. McKusick Lake 2017 Elevations

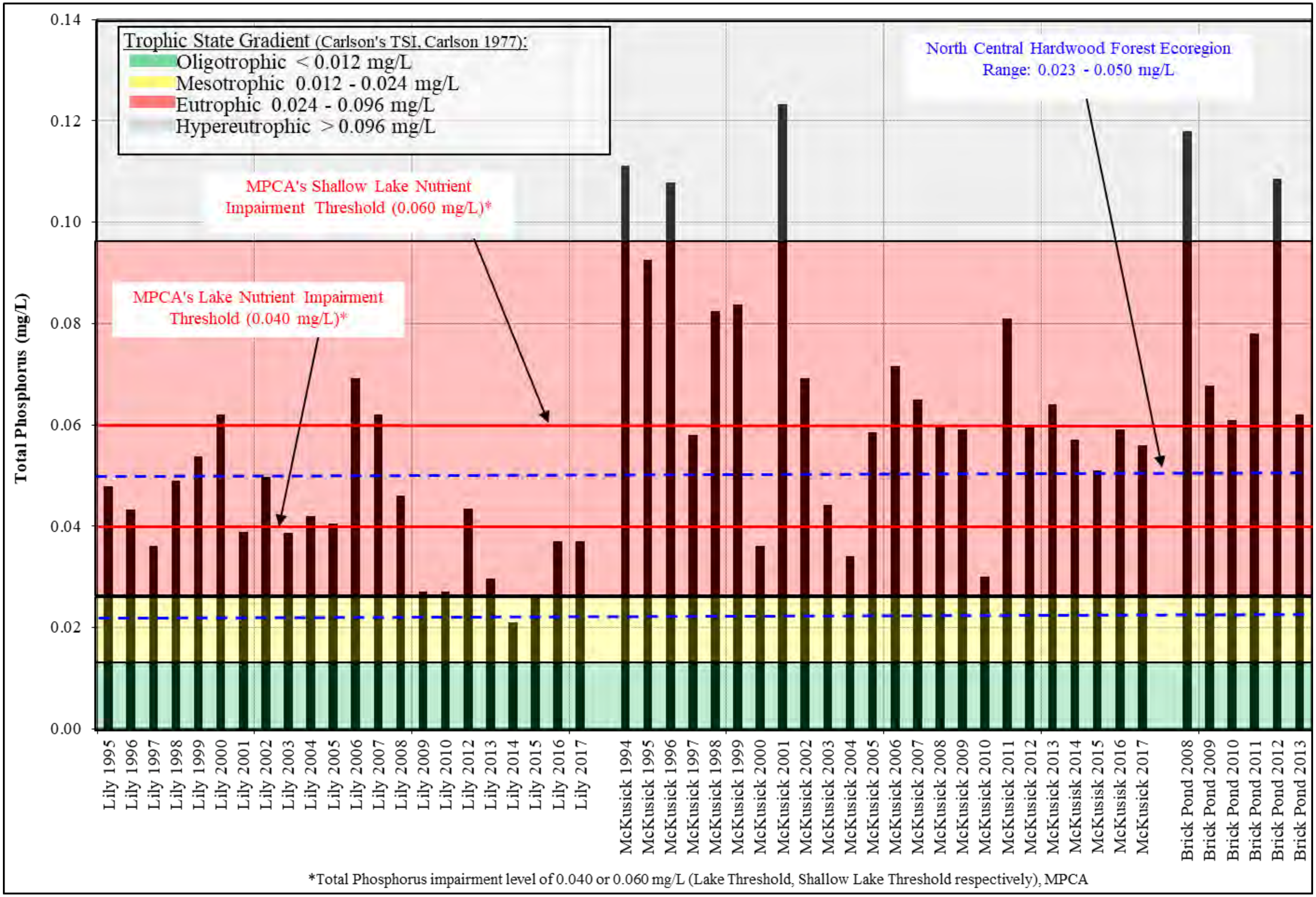


Figure 4. MSCWMO Historic Summer Average Total Phosphorus

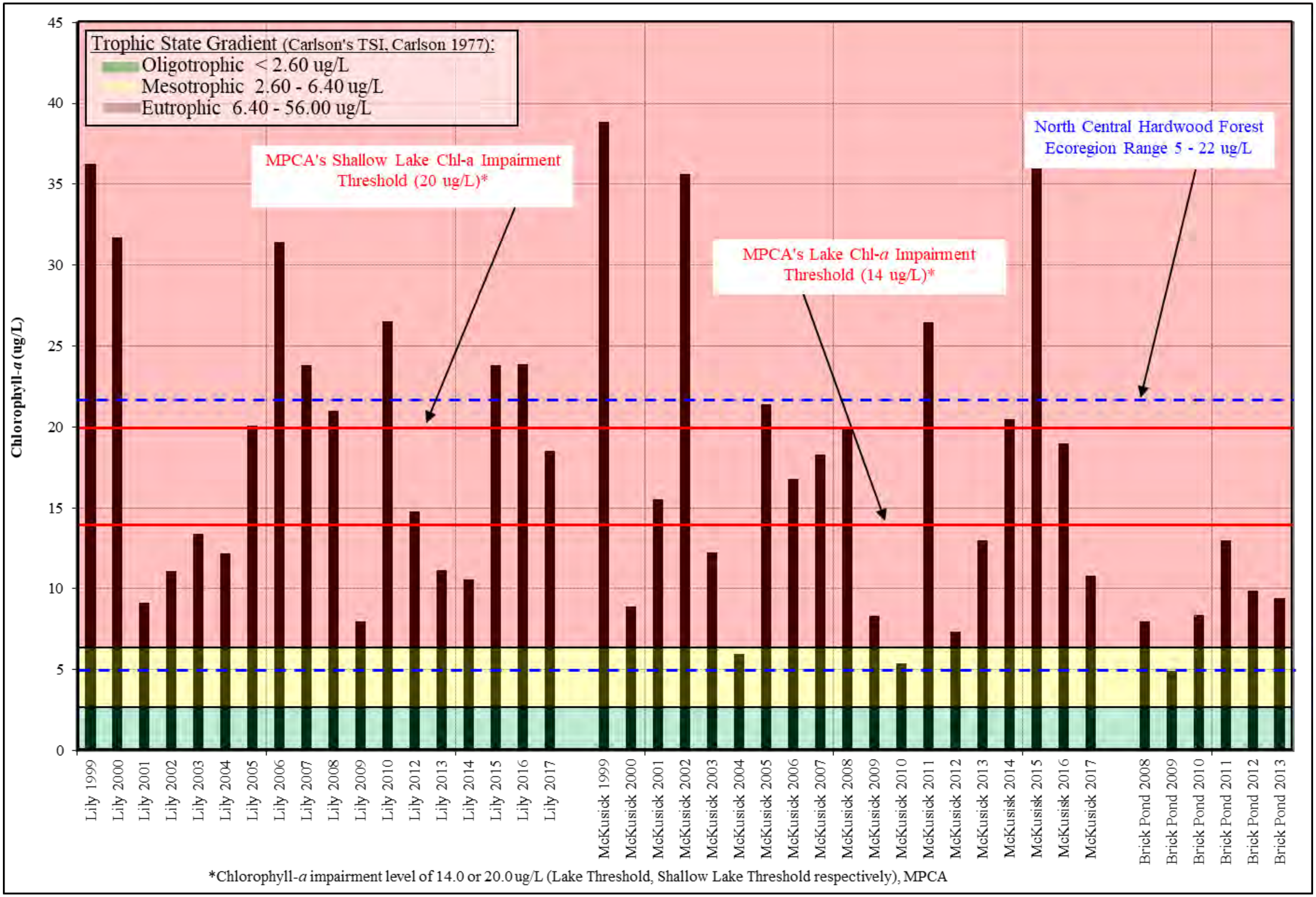


Figure 5. MSCWMO Historic Summer Average Chlorophyll-α

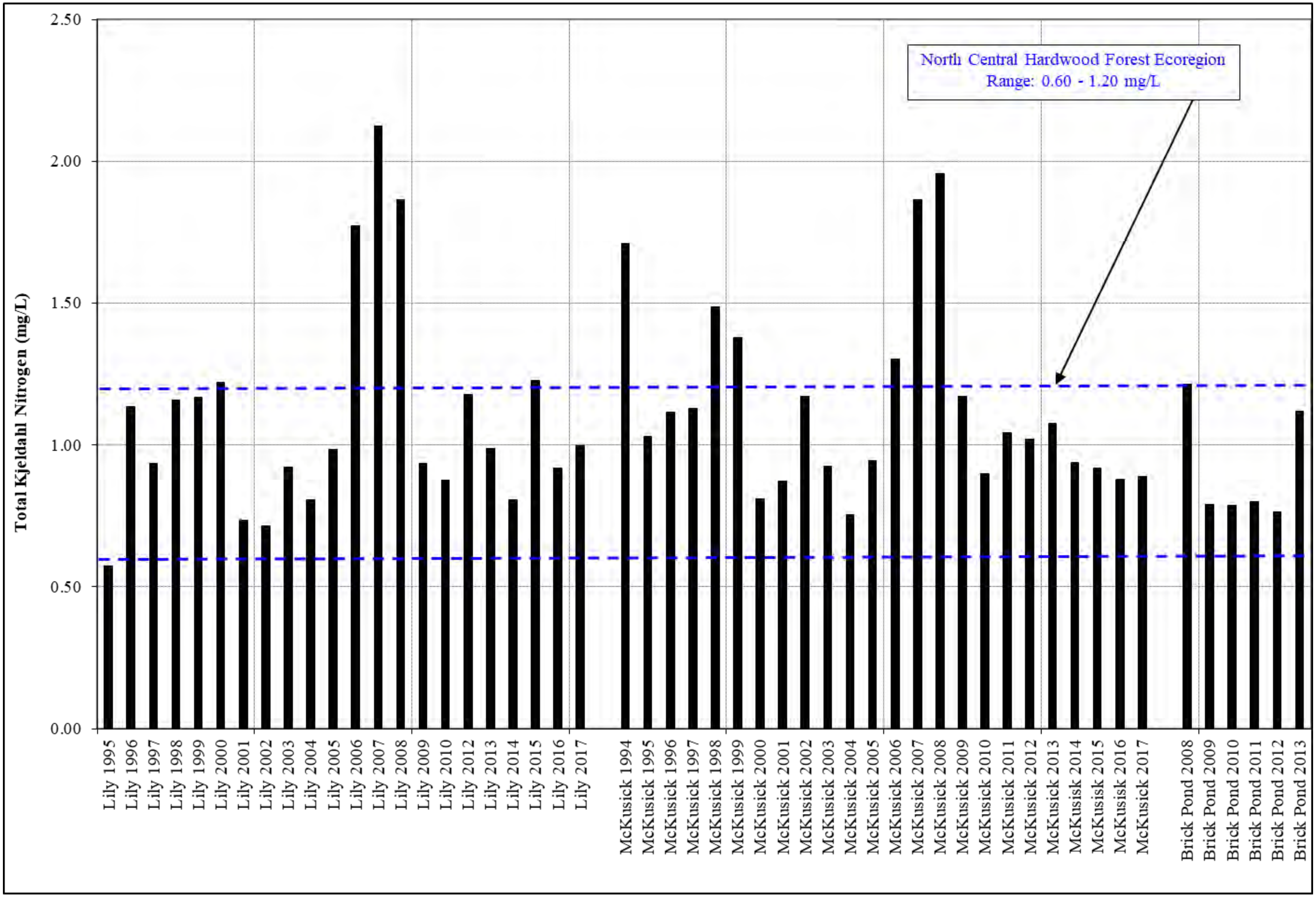


Figure 6. MSCWMO Historic Summer Average Total Kjeldahl Nitrogen

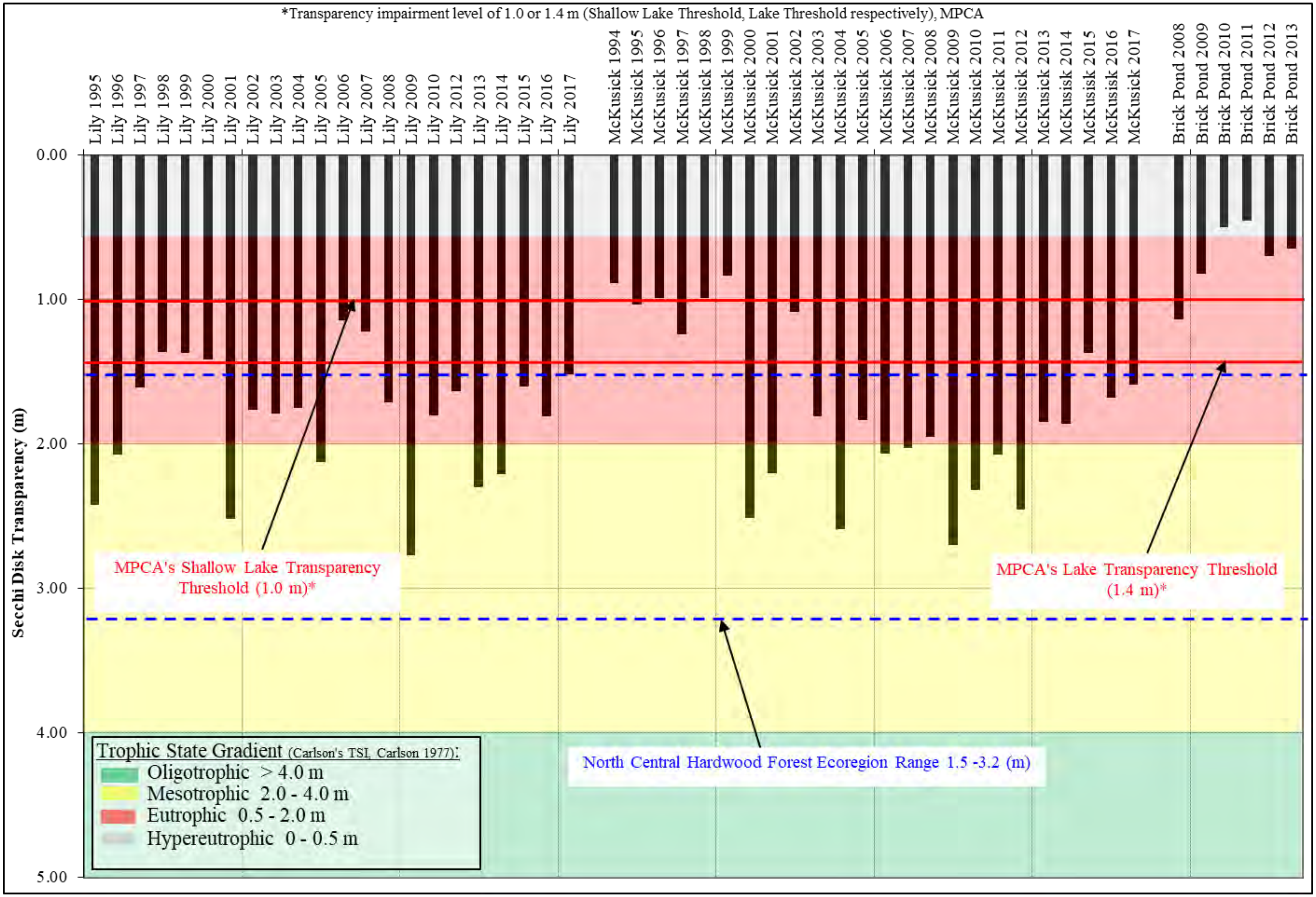


Figure 7. MSCWMO Historic Summer Average Secchi Data

3. BROWN'S CREEK DIVERSION STRUCTURE

As part of Brown's Creek Watershed District long-term monitoring, the WCD collected grab samples and automated flow-weighted samples during both base flow and storm event conditions at the Brown's Creek Diversion Structure for BCWD in 2017, and that data is provide to the MSCWMO. The City of Stillwater constructed the diversion structure in June of 2003, as part of the completion of the Trout Stream Mitigation Project (TSMP). It has been functioning to divert water from the 1,800-acre annexation area, away from Brown's Creek through McKusick Lake, and ultimately to the St. Croix River. While this diversion structure will keep the warmer urban stormwater runoff from the southern tributary out of the temperature and nutrient sensitive Brown's Creek Ravine, it means that this water will be discharged to McKusick Lake, and could affect the lake water quality. Data collected at this site by the WCD includes continuous stage and total discharge, and water quality samples analyzed for nutrients, sediment, metals, and bacteria. Discharge decreased by more than half from the year prior to a total volume of 39,625,672 cubic feet exported to McKusick Lake (Table 4 and Table 5). All stream flow and chemistry data from 2017 can be found in Table 4 through Table 6.

The TP load to McKusick Lake decreased in 2017 from the year prior to 784 pounds of phosphorus (0.203 pounds per acre) (Table 4 and Table 5). The June base sample had an extremely high TP concentration compared to other base flow samples and was excluded when completing loading calculations. The TSS load decreased from the year prior to 596,382 pounds of sediment, equating to 154.70 pounds per acre of watershed land (Table 4 and Table 5).

One source of the high TP and TSS loads in the diversion drainage is an erosional head cut north of Boutwell Road, upstream of the monitoring location. The creek is eroding its bed and banks at this location, and actions taken to address this issue will significantly reduce TP and TSS loads to McKusick Lake. The Iron Enhanced Sand Filter (IESF) upstream of the monitoring site continues to operate to reduce TP loads in this subwatershed.

In 2017 the number and severity of metal standard exceedances were much lower than past years. Exceedances are based on the MPCA metal standards. The calculation of metal standards are described in the Minnesota Administrative Rules Part 7050.0222 and are divided into three categories of toxicity; chronic, maximum, and final acute value (FAV). The chronic standard protects organisms from long term exposure to a pollutant with minimal effects, the maximum standard from short term exposure with no or little mortality, and the FAV is the concentration at which mortality can be expected. The maximum standard for copper was exceeded one time, and the chronic standard two times. The chronic standard for lead was exceeded four times. A summary of metals results can be seen in (Table 6). The occurrence of heavy metal exceedances exported to McKusick Lake and its wetland complex are particularly concerning due to the potential to kill aquatic life at high concentrations, as opposed to nutrient or sediment loading which typically degrades habitat and populations of aquatic life over time. The most likely source of these elevated metals is the erosion occurring upstream of the site. Additional sources may be from unseen deposits of improperly disposed waste, such as batteries, on the landscape from decades of settlement.

Table 4. Brown’s Creek Diversion Structure Drainage Historical Annual Discharge and Loading Amounts

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Brown's Creek Diversion Structure										
Discharge (cf)	29,397,219	31,166,264	38,197,468	52,981,553	21,810,789	46,435,271	53,519,017	46,276,327	70,780,581	39,625,672
Total pounds of Phosphorus exported	206	544	608	2,099	251	527	392	1,837	1,574	784
TP (lbs/ac/yr)	0.053	0.141	0.158	0.544	0.065	0.137	0.102	0.447	0.408	0.203
Total pounds of TSS exported	59,313	227,372	353,007	1,387,050	127,435	211,977	99,532	1,008,346	1,533,496	596,382
TSS (lbs/ac/yr)	15.39	58.98	91.57	359.81	33.06	54.99	25.82	261.57	397.79	154.70

Table 5. Brown's Creek Diversion Structure Drainage 2017 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

	Sample Collection Time				Loading Interval					
Sample Type	Start	End	TSS (mg/L)	TP (mg/L)	Start	End	Interval Volume (cf)	Interval Volume (ac-ft)	Interval TSS (lb)	Interval TP (lb)
Base*			10	0.094	1/1/2017 0:00	2/20/2017 12:00	1,745,280	40.09	1,090	10.27
Storm*			1,465	1.567	2/20/2017 12:00	2/21/2017 7:00	171,000	3.93	15,639	16.72
Base*			10	0.094	2/21/2017 7:00	4/15/2017 0:00	1,821,600	41.84	1,137	10.72
Storm*			1,465	1.567	4/15/2017 0:00	4/15/2017 7:00	40,320	0.93	3,687	3.94
Base*			10	0.094	4/15/2017 7:00	4/19/2017 15:00	149,760	3.44	93	0.88
Storm*			1,465	1.567	4/19/2017 15:00	4/20/2017 18:00	213,840	4.91	19,557	20.91
Base*			10	0.094	4/20/2017 18:00	4/25/2017 15:00	168,480	3.87	105	0.99
Storm			1,465	1.567	4/25/2017 15:00	4/26/2017 18:00	213,248	4.90	19,502	20.85
Base Grab	4/27/2017 8:50	4/27/2017 8:50	13	0.077	4/26/2017 18:00	4/30/2017 22:00	550,075	12.63	446	2.64
Storm Composite**	5/1/2017 0:28	5/1/2017 6:06	7,950	4.130	4/30/2017 22:00	5/1/2017 7:00	147,683	3.39	73,293	38.08
Storm			1,465	1.567	5/1/2017 7:00	5/2/2017 19:00	1,011,080	23.22	92,468	98.87
Base			10	0.094	5/2/2017 19:00	5/15/2017 12:00	3,549,504	81.53	2,216	20.89
Storm			1,465	1.567	5/15/2017 12:00	5/17/2017 17:00	1,046,250	24.03	95,684	102.31
Storm Composite	5/17/2017 21:56	5/18/2017 11:44	1,880	1.780	5/17/2017 17:00	5/18/2017 12:00	982,224	22.56	115,275	109.14
Base			10	0.094	5/18/2017 12:00	5/20/2017 11:00	2,283,770	52.46	1,426	13.44
Storm Composite	5/20/2017 17:25	5/21/2017 5:09	498	0.774	5/20/2017 11:00	5/21/2017 12:00	1,858,450	42.69	57,776	89.80
Base			10	0.094	5/21/2017 12:00	5/24/2017 8:00	4,119,580	94.62	2,572	24.25
Base Grab	5/25/2017 8:26	5/25/2017 8:26	13	0.074	5/24/2017 8:00	5/26/2017 8:00	1,558,780	35.80	1,265	7.20
Base			10	0.094	5/26/2017 8:00	6/26/2017 8:00	4,442,065	102.03	2,773	26.15
Base Grab	6/27/2017 8:25	6/27/2017 8:25	6	0.078	6/26/2017 8:00	6/28/2017 5:00	123,409	2.83	46	0.60
Storm Composite	6/28/2017 10:02	6/29/2017 13:43	902	0.882	6/28/2017 5:00	6/29/2017 14:00	176,356	4.05	9,930	9.71
Base			10	0.094	6/29/2017 14:00	7/12/2017 2:00	835,084	19.18	521	4.92
Storm			1,465	1.567	7/12/2017 2:00	7/12/2017 14:00	50,137	1.15	4,585	4.90
Base			10	0.094	7/12/2017 14:00	7/17/2017 22:00	265,861	6.11	166	1.56
Storm			1,465	1.567	7/17/2017 22:00	7/18/2017 8:00	43,607	1.00	3,988	4.26
Base			10	0.094	7/18/2017 8:00	7/23/2017 15:00	378,227	8.69	236	2.23
Base Grab	7/24/2017 15:00	7/24/2017 15:00	9	0.103	7/23/2017 15:00	7/25/2017 15:00	92,443	2.12	52	0.59
Base			10	0.094	7/25/2017 15:00	8/14/2017 0:00	952,359	21.87	595	5.61
Storm			1,465	1.567	8/14/2017 0:00	8/14/2017 7:00	51,543	1.18	4,714	5.04
Base			10	0.094	8/14/2017 7:00	8/16/2017 20:00	258,184	5.93	161	1.52
Storm Composite	8/16/2017 23:00	8/17/2017 8:25	2,580	2.830	8/16/2017 20:00	8/17/2017 14:00	283,544	6.51	45,667	50.09
Base			10	0.094	8/17/2017 14:00	8/26/2017 0:00	1,347,153	30.94	841	7.93
Storm			1,465	1.567	8/26/2017 0:00	8/26/2017 10:00	55,803	1.28	5,103	5.46
Base Grab	8/30/2017 8:25	8/30/2017 8:25	13	0.101	8/26/2017 10:00	8/31/2017 8:00	434,563	9.98	353	2.74
Base			10	0.094	8/31/2017 8:00	9/26/2017 8:00	1,397,784	32.11	873	8.23
Base Grab	9/27/2017 8:24	9/27/2017 8:24	13	0.110	9/26/2017 8:00	10/2/2017 18:00	330,021	7.58	268	2.27
Storm			1,465	1.567	10/2/2017 18:00	10/3/2017 3:00	94,529	2.17	8,645	9.24
Base			10	0.094	10/3/2017 3:00	10/23/2017 10:00	3,212,070	73.78	2,005	18.91
Base Grab	10/24/2017 10:01	10/24/2017 10:01	3	0.117	10/23/2017 10:00	10/30/2017 10:00	803,366	18.45	150	5.87
Base*			10	0.094	10/30/2017 10:00	12/6/2017 0:00	1,580,400	36.30	987	9.30
Base*			10	0.094	12/6/2017 0:00	1/1/2018 0:00	786,240	18.06	491	4.63
Storm Composite Average			1,465	1.567						
Base Average			10	0.094						
All Average			539	0.630						
Total							**39,625,672**	**910**	**596,382**	**784**
Brown's Creek Major Subwatershed Total Acres							3,855			
Total TSS/TP(lb/ac/yr)									154.70	0.203
Total TSS/TP (kg/ha/yr)									173.40	0.228

Italics indicate estimated concentrations based on average base and storm flow concentrations.
*Interval volumes were estimated using similar flow conditions.
**Sample results excluded from averages

Table 6. Brown's Creek Diversion Structure Drainage 2017 Chemistry Results

Sample Type	Start	End	TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	Dissolved P (mg/L)	Copper (mg/L)	Nickel (mg/L)	Lead (mg/L)	Zinc (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Chloride (mg/L)	Nitrite N (mg/L)	Nitrate N (mg/L)	Ammonia Nitrogen (mg/L)	Hardness (mg/L _CaCO3)
Storm Composite	5/1/2017 0:28	5/1/2017 6:06	7,950	2,310	21.00	4.130	0.052	0.02740	0.03240	0.02650	0.11500	0.00097	0.03320	38.7	0.03	0.38	~0.04	176
Storm Composite	5/17/2017 21:56	5/18/2017 11:44	1,880	570	7.50	1.780	0.083	0.01500	0.01630	0.01380	0.06030	0.00050	0.01710	48.6	<0.03	0.14	0.07	116
Storm Composite	5/20/2017 17:25	5/21/2017 5:09	498	114	3.50	0.774	~0.038	0.00630	0.00670	0.00570	0.02320	~0.00020	0.00620	54.4	<0.03	0.08	<0.02	84
Storm Composite	6/28/2017 10:02	6/29/2017 13:43	902	338	4.80	0.882	~0.048	0.00670	0.00760	0.00490	0.04370	~0.00026	0.00700	58.0	<0.03	0.16	<0.02	208
Storm Composite	8/16/2017 23:00	8/17/2017 8:25	2,580	567	14.00	2.830	0.092	0.02030	0.02330	0.01780	0.09460	0.00079	0.01930	41.8	<0.03	0.23	<0.02	94
Base Grab	4/27/2017 8:50	4/27/2017 8:50	13	~5	0.61	0.077	<0.020	<0.00030	0.00100	~0.00042	~0.00150	<0.00020	0.00063	49.6	<0.03	0.32	0.07	140
Base Grab	5/25/2017 8:26	5/25/2017 8:26	13	5	0.77	0.074	<0.020	0.00075	0.00068	~0.00035	~0.00140	<0.00020	0.00046	89.1	<0.03	0.11	~0.04	68
Base Grab	6/27/2017 8:25	6/27/2017 8:25	6	3	0.49	0.078	~0.025	~0.00053	0.00082	~0.00028	0.00290	<0.00020	0.00044	57.8	<0.03	0.54	~0.05	200
Base Grab	7/24/2017 15:00	7/24/2017 15:00	9	4	0.42	0.103	0.080	0.00110	0.00120	~0.00026	~0.00120	<0.00020	0.00068	53.6	<0.03	0.72	~0.04	256
Base Grab	8/30/2017 8:25	8/30/2017 8:25	13	5	0.65	0.101	~0.034	~0.00054	0.00098	~0.00031	<0.00500	<0.00020	0.00073	52.3	<0.03	0.43	~0.04	212
Base Grab	9/27/2017 8:24	9/27/2017 8:24	13	4	0.50	0.110	~0.047	~0.00053	0.00085	~0.00036	<0.00500	<0.00020	0.00079	56.2	<0.03	0.56	~0.03	235
Base Grab	10/24/2017 10:01	10/24/2017 10:01	3	~2	0.46	0.117	~0.040	~0.00030	0.00062	~0.00013	<0.00500	<0.00100	0.00036	66.2	<0.03	0.52	~0.02	215

Green	Exceeds Water Quality Standard
Orange	No Exceedance Determinable
Yellow	Exceeds Chronic Standard
Cyan	Exceeds Max Standard
Dark red	Exceeds Final Acute Standard

STREAM AND STORMWATER MONITORING

A. LILY LAKE INLET MONITORING

In 2015, the MSCWMO received grant funding to conduct targeted water quality monitoring on Lily Lake with the goal of identifying priority areas for nutrient load reduction to the lake. The MSCWMO worked closely with the WCD to develop and implement a monitoring plan to achieve this goal.

In order to identify the catchments to Lily Lake contributing the majority of the nutrient load, the WCD recommended the following plan. In 2015 all outfalls that directly discharge into Lily Lake were identified. Flow meters were installed at seven outfalls to collect continuous discharge data. Grab samples were also collected at each outfall during storm events in order to estimate loading to Lily Lake. An eighth outfall was identified after the initial location selection process, but no logger was installed at this site. Observations of the flow occurring at this location were made while the other seven were visited during storm events and it was determined that flow from the inlet was negligible. Data collected in 2015 indicated that approximately 95% of the discharge to Lily Lake was coming from four of the eight identified catchments.

In 2016 the four catchments with the largest loading contribution were monitored. Additional samples were collected at the Greeley Street location in order to develop a more accurate loading estimate and to better characterize the variety of flow regimes present at that site. This monitoring confirmed data collected in 2015.

In 2017 monitoring focused on the Greeley Street catchment recording; stage, velocity, and total discharge. Discharge was calculated using an area/velocity relationship from a sensor located at the Greeley Street catchment. Total reported discharge was calculated using both logged data and estimations, which were made during periods when logged data was unavailable. The discharge to Lily Lake decreased by nearly half form the prior year to a total volume of 4,839,440 cubic feet. All discharge data from 2017 can be found in Table 7. Additionally, grab samples were collected and analyzed for the following water quality parameters; Total

Phosphorus (TP), Total Kjeldhal Nitrogen (TKN), and Total Suspended Solids (TSS). Grab samples were divided into base and storm conditions based on logged data. Water quality results can be found in Table 8.

Sample results in 2017 were similar to results in prior years. The Greeley Street catchment base flow grab samples had low levels of TP and TSS. The 2017 average TP was 0.06 mg/L; similar to the 0.07 mg/L seen in 2016. The 2017 average TSS concentration was 3 mg/L; similar to the 2 mg/L seen in 2016 (Table 7, Table 8, Figure 8, and Figure 9). Storm event sample results continued to be much higher than base samples. The average TP concentration for storm samples was 0.104 mg/L which was lower than the 2016 average concentration of 0.437 mg/L. The average TSS concentration in 2017 was 35 mg/L; lower than the average concentration of 233 mg/L in 2016 (Table 7, Table 8, Figure 8, and Figure 9). The TP load to Lily Lake from Greeley Street was 21.65 lbs., lower than the load of 62.28 lbs. in 2016. The TSS load was 3,385.62 lbs., lower than the 21,068.28 lbs. in 2016. The lower concentrations of TP and TSS for storm samples may be due to limited ability to collect storm samples in 2017 due to a decrease in the total storm events. Lower results should be considered with caution. 2017 results support previous years' results that the majority of loading to Lily Lake occurs during storm events (Table 7).

It is believed that the method employed to take the 8/30/17 and 10/24/17 samples contributed to the outlier results. These samples were taken during very low flow periods and there may have been suspension of sediment during the sampling process, which would contribute to higher sample results. If a more reliable method of sample collection cannot be identified and implemented in 2018, sampling will not occur during these conditions.

Table 7. Greeley Street 2017 Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading

Site	Date range	Total Estimated Flow (CF)	Total Estimated Flow (ac-ft)	Proportion of Total Flow	Average Phosphorus Concentration (mg/L)	Phophorus Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range (mg/L)	TP Load (lbs.)	TSS Load (lbs.)
Greeley Street Base	4/7 - 10/31*^	3,556,044	81.68	0.7348	0.06	0.045-0.083	3	1-7	13.32	621.57
Greeley Street Storm	4/7 - 10/31*	1,283,396	29.48	0.2652	0.104	0.089-0.119	35	28-41	8.33	2764.05

*Indicates that estimations of flow occur during period using similar logged flow conditions

^8/30 and 10/24 results excluded from averages and ranges

Table 8. Greeley Street 2017 Water Quality Results

Date	Greeley Street			
	Sample Type	TP (mg/L)	TSS (mg/L)	TKN (mg/L)
4/27/2017	Base	~0.045	~1	0.86
5/16/2017	Storm	0.119	41	1.6
5/24/2017	Base	~0.049	3	0.68
6/22/2017	Storm	0.089	28	0.92
6/27/2017	Base	0.061	~2	0.98
7/24/2017	Base	0.083	~1	0.82
8/30/2017*	Base	0.203	20	1.6
10/3/2017	Base	0.062	7	0.58
10/24/2017*	Base	0.322	92	2.8

*Result excluded from averages

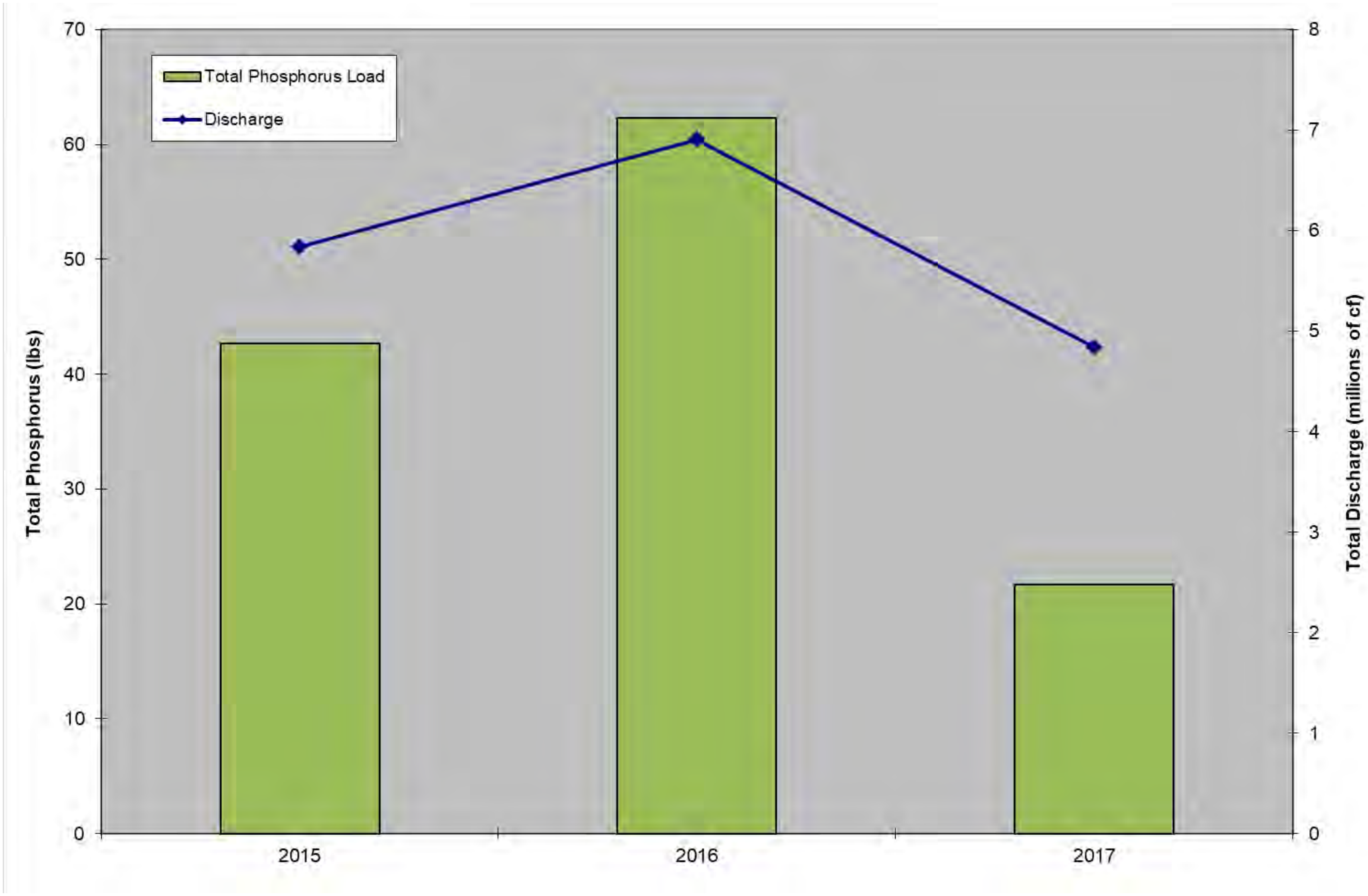


Figure 8. Greeley Street Annual Discharge and Total Phosphorus Load

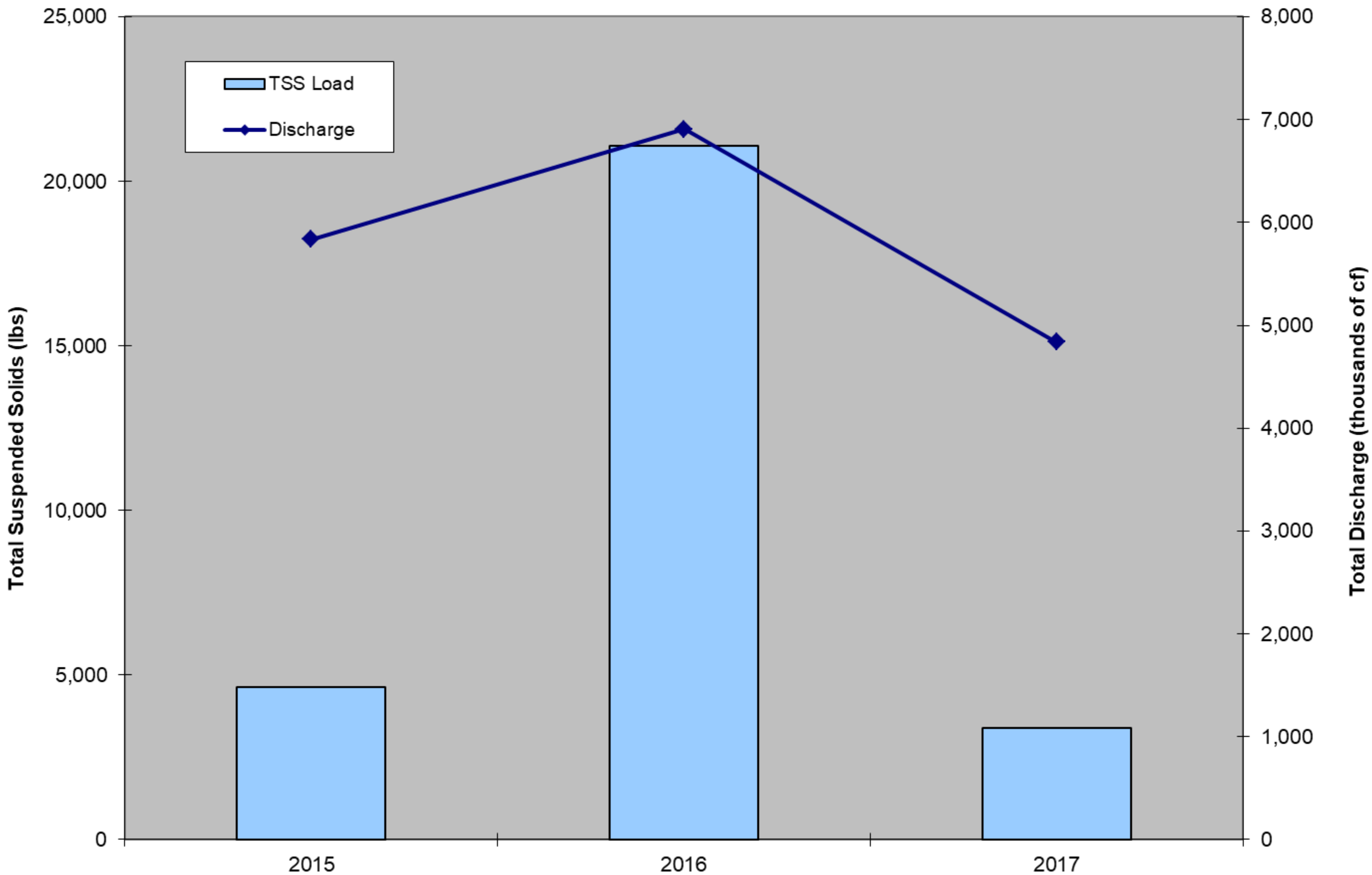


Figure 9. Greeley Street Annual Discharge and Total Suspended Solids Load

B. PERRO CREEK MONITORING

The goal of monitoring Perro Creek in 2016 was to identify where the greatest contribution of nutrients and sediment to the Saint Croix River was occurring. Monitoring continued in 2017 to further refine 2016 observations. In 2017 base and storm grab samples were collected at Perro Creek at the Perro Pond Outlet and the Perro Creek at the Diversion Structure sites, and analyzed for Total Phosphorus (TP), Total Kjeldhal Nitrogen (TKN), Total Suspended Solids (TSS) and *E. coli*. Samples were collected and analyzed for *E. coli* only at the Perro Creek at 6th Street site. Samples were not collected at Perro Pond Outlet Direct to the St. Croix since results from 2016 show that the water quality results were similar to the results from Perro Creek at the Perro Pond Outlet. Monitoring will continue at these sites in 2018.

Perro Creek at the Perro Pond Outlet had flow sample results compared to Perro Creek at the Diversion Structure, and compared to 2016 results. Perro Creek at the Perro Pond Outlet had a phosphorus range from 0.020-0.049 mg/L with an average concentration of 0.020 mg/L. The average TSS concentration was 2 mg/L with a range of 1-5 mg/L (Table 9 and Table 10). In 2017 Perro Creek at the Diversion Structure had lower average results, and a lower range than 2016 results. The average phosphorus concentration was 0.069 mg/L with a range of 0.020-0.218 mg/L. The average TSS concentration was 20 mg/L; lower than 2016. Perro Creek at the Diversion Structure TSS results had a range of 1-76 mg/L, which was a smaller range than 2016 (Table 9 and Table 10).

Differences in *E. coli* between sites were seen in 2017 from Perro Creek at the Perro Pond Outlet to Perro Creek at the Diversion Structure. The *E. coli* results at Perro Creek at the Perro Pond Outlet were lower than 2016. Perro Creek at 6th Street had higher levels of *E. coli* than Perro Creek at the Diversion Structure for half of the samples taken despite being upstream; however the highest individual *E. coli* result from all three sites occurred at Perro Creek at the Diversion Structure (Table 11). According to the MPCA standards, Perro Creek is exceeding impairment standards at 6th Street from June through September (Table 12). Impairment standards are based on MPCA protocol which includes the last ten years of data and requires at least 5 samples in a calendar month to calculate the geomean. In 2018 *E. coli* will be collected at ten sites between

Perro Creek at the Perro Pond Outlet and Perro Creek at 3rd Ave to further quantify this relationship and help delineate sources of *E. coli*.

Perro Creek at the Diversion Structure experienced many challenges. The area velocity sensor was moved from its location in 2016 due to the V-notched weir impacting the accuracy of stage, velocity, and flow data. The 2017 location also experienced different challenges that also prevented accurate estimation of discharge. The site is prone to channel obstruction from various sources, including debris. There were a few occasions of manipulation of the creek, and even the structure itself which caused issues with collecting accurate data. Manipulations caused sediment deposition, which constantly changed the shape and depth of the channel. The frequent occurrence of obstructions from various sources impacted the consistency and quality of logged data. This inability to collect reliable data made loading calculations not feasible. Additional monitoring is planned for 2018 to further refine these observations and correct issues encountered in 2017.

Table 9. Perro Creek 2017 Total Suspended Solids (TSS) and Total Phosphorus (TP)

Site	Estimated Discharge (CFS)	Average Phosphorus Concentration (mg/L)	Phosphorus Range (mg/L)	Average TSS Concentration (mg/L)	TSS Range
Perro at Perro Pond Outlet	32,286,300	0.029	0.020-0.049	2	1-5
Perro at Diversion Structure Overflow	9,652,720	N/A	N/A	N/A	N/A
Perro at Diversion Structure	N/A	0.069	0.020-0.218	20	1-76

Table 10. Perro Creek 2017 Water Quality Results

Date	Perro Creek at the Diversion Structure			Perro Creek at Perro Pond Outlet		
	TP (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	TKN (mg/L)
5/16/2017	0.095	34	1.00	~0.049	4	0.78
5/25/2017	<0.020	~1	0.24	<0.020	~1	0.44
6/22/2017	0.218	76	1.70	~0.031	5	1.00
6/27/2017	~0.031	6	0.47	~0.030	~1	0.42
7/24/2017	~0.043	~1	0.31	~0.030	~1	0.42
8/3/2017	0.094	20	0.74	~0.029	4	0.54
8/9/2017	<0.020	3	0.41	NA	NA	NA
8/30/2017	<0.020	8	0.40	~0.030	~2	0.37
9/26/2017	0.120	60	0.98	<0.020	~1	0.53
10/3/2017	~0.023	12	0.38	~0.024	~1	0.38
10/24/2017	0.071	4	0.29	~0.024	~2	0.26

Table 11. Perro Creek 2017 *E. coli* Results

Site	*E. coli* Results					
	5/25/2017	6/22/2017	7/24/2017	8/30/2017	9/26/2017	10/24/2017
Perro at Perro Pond Outlet	18	38	46	13	54	80
Perro at 6th Street	249	461	34	80	649	78
Perro at Diversion Structure	146	387	56	228	>2420	68

Table 12. Monthly Geometric Means of *E. Coli* Latest Ten Years

Monthly Geometric Means for *E. coli* (#/100 mL)

Site	April	May	June	July	August	September	October
Perro Creek at 6th Street	Insufficient Data	Insufficient Data	167	138	150	251	Insufficient Data

(yellow)	Exceeds geometric mean of 126 #/100mL from not less than 5 samples in a calendar month
(green)	10% of samples taken in the last 10 years exceed 1,260 #/100mL (Doesn't necessarily exceed geometric mean standard)

*Based on MPCA protocol: "*Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*"

MSCWMO: CONCLUSIONS AND RECOMMENDATIONS

A. LAKES

Lake monitoring in MSCWMO continues to provide valuable baseline water quality information. To determine the health of the lakes in MSCWMO, physical and chemical parameters are compared on a year-to-year basis and to other lakes in the region. Water quality in a lake depends on a number of different variables such as: size of the contributing watershed, external nutrient sources, depth of the lake, and the current amount of nutrients available to be periodically released from the lake bottom. Low water quality ratings of MSCWMO lakes are most likely due to long-term contribution of urban runoff (Lily Lake) or due to the sensitivity of shallow lakes being prone to summertime mixing (McKusick Lake). Shallow lakes typically exist in a low algal production, clear-water state with abundant aquatic macrophytes or in a high-algal production, turbid water state. Shallow lakes may not completely stratify in the summer, and therefore have the capability to continually mix throughout the summer. That mixing causes phosphorus to be distributed throughout the water column, causing more frequent and thick algal blooms. This is unlike deeper, stratified lakes where phosphorus below the thermocline is not available for primary production.

The MPCA listed both Lily and McKusick Lake on the 303(d) Impaired Waters list for nutrient/eutrophication impairment; however McKusick Lake was delisted in 2012. If a water body is listed, it indicates that it does not currently meet water quality criteria. In order to meet those criteria, a total maximum daily load (TMDL) must be implemented. A TMDL outlines what pollutants are degrading the water quality and what will need to be done in order to meet current water quality standards. The MPCA had tentatively scheduled a three lake TMDL for Long Lake (Brown's Creek Watershed District), Lily Lake, and McKusick Lake in 2010, but because of improving water quality trends in those lakes over recent years the TMDL has been postponed. The MSCWMO, BCWD, and the City of Stillwater will utilize the City of Stillwater's existing Lake Management Plan, the completed Lily and McKusick Lake subwatershed assessments, and Lily Lake inlet monitoring data to further guide project implementation in an effort to continue to improve the water quality of the lakes. The MPCA will consider the need for a TMDL again in the future.

Summertime (June-September) TP, chl-α, and Secchi disk transparency averages for have remained relatively consistent over the last twenty years in Lily Lake with the exceptions of 1995, 2001, 2009, 2013, and 2014 where overall water quality dramatically improved (Figure 4, Figure 5, and Figure 7). In 2001 phosphorus and chl-α levels dropped and the lake grade improved significantly. In 2006-2008, summer average TP, chl-α, and Secchi disk transparency deteriorated when compared to the averages seen from 2001 to 2005. In 2017 Lily Lake received a grade of a C+, the long-term normal lake grade.

The cause of these one-year increases (1995, 2001, 2009, 2013, and 2014) in water quality is presently unknown, and there may be many possible explanations which could be investigated further in the future. Lily Lake has received herbicide and algaecide treatments from 1995-2011 and 2016-2017. Native buffer planting at the public access was installed in 2010. The Lily Lake watershed underwent a subwatershed assessment in 2010. As a result, fifteen raingardens were constructed in the Lily Lake watershed from 2011-2012, and six large raingardens were installed in 2014. The first effects of these BMPs may have been seen from 2012 to 2017 monitoring seasons with the 2016 season having a statistically significant ($p<0.05$) improving trend for TP which continued in 2017. Continued monitoring is needed to show changes to long term trends due to the implementation of these BMPs. For more information about the Lily Lake subwatershed assessment refer to the Lily Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/LILY-Assessment-Report-FINAL.pdf.

A subwatershed assessment was conducted on the McKusick Lake watershed in 2010. In 2011 six raingardens were constructed as a result of the subwatershed assessment. With renewed funding, seven additional raingardens were to be installed in the McKusick Lake watershed in 2013 but because of issues with utilities, six larger raingardens were installed in 2014. The impacts of previously installed raingardens may have been seen in 2017 with statistically significant ($p<0.05$) improving trends for average TP and average Secchi disk transparency. For more information on the McKusick Lake subwatershed assessment refer to the McKusick Lake Stormwater Retrofit Assessment found at http://mscwmo.org/wp-content/subwatershed/McKUSICK-Assessment-Report-FINAL.pdf.

B. STREAMS

The targeted monitoring of Lily Lake had the goal of more accurately identifying the major sources of nutrients to the lake and to help steer targeting and design of stormwater management practices. Short term monitoring limits the number of conclusions that can be drawn. Using the average concentrations and recorded flow data, an estimate of phosphorus loading to the lake was developed. 2016 results indicated 78% of the total phosphorus load to Lily Lake was occurring during storm runoff events. The remaining 22% of the phosphorus load was from base flow periods, with very low phosphorus concentration, from Brick pond to Lily Lake, as indicated by the monitoring station at Greeley Street. However, base flow from Brick Pond accounted for 65% of the total discharge to the lake. For the majority of the 2016 monitoring period, phosphorus concentrations coming out of Brick Pond were below 0.070 mg/L, and peaked just above 0.100 mg/L during the height of the growing season. Phosphorus results in 2017 from Brick Pond were lower on average than 2016 with a majority of samples being 0.063 mg/L or less, with the highest result being 0.083 mg/L. While further reducing the phosphorus concentration discharging from Brick Pond is possible, it is not recommended due to the comparatively small reduction in phosphorus load to Lily Lake.

As stated above, 78% of the phosphorus load to Lily Lake is occurring during storm events. The highest contributing catchments during these events are Greeley Street and Lake Street, which combined account for 55% of the load. The phosphorus load from Greeley Street appears to be discharge driven, as the average phosphorus concentration during storm events was on the lower end of those observed yet the total flow was roughly triple that of the other sites. Also of note is that it appears the majority of this flow is coming from direct street runoff and not through Brick Pond. This was again observed in 2017 at Greeley Street with storm event phosphorus results varying from 0.089 mg/L to 0.119 mg/L. Base flow from Brick Pond had low TSS results with the highest result being 7 mg/L. Storm results for TSS peaked at 41 mg/L. These results confirmed the previous investigation in regards to the Greeley Street catchment having low sample results for TP and TSS during base flow and higher results during storm events.

Therefore, it is recommended that steps be taken to implement best management practices in the areas of the Greeley Street catchment that are directly discharging to Lily Lake, with less of an emphasis being placed on water entering Brick Pond. Continued monitoring at the Greeley Street catchment will help monitor the impact of BMPs installed in the Greeley Street catchment.

Loading estimates indicate the next priority would be the Lake Street catchment, which showed the highest average and discrete phosphorus concentrations. However, reducing the discharge and/or the phosphorus concentration at any of the four catchments identified as high contributors should have a significant impact on improving the water quality in Lily Lake. Therefore, it is recommended that these results be used in conjunction with implementation factors of stormwater management practices for targeting improvements to the catchments.

Monitoring of Perro Creek started in 2016 to determine where the greatest contribution of nutrients and sediment to the Saint Croix River was occurring. This investigation continued in 2017. TP and TSS results at Perro Creek at the Perro Pond Outlet were very low in 2016 and 2017. 2017 phosphorus results vary from less than 0.020 mg/L to 0.049 mg/L, and TSS results varied from 1 mg/L to 5 mg/L. Since these results are low and consistent it can be assumed that under current conditions Perro Pond would not be a significant source of nutrient loading to the Saint Croix River, and therefore not benefit significantly from retrofits.

Phosphorus results from 2016 and 2017 show an increase in phosphorus from Perro Creek at the Perro Pond Outlet to Perro Creek at the Diversion Structure. Average phosphorus results in 2017 were 0.03 mg/L at Perro Creek at the Perro Pond Outlet and 0.07 mg/L at Perro Creek at the Diversion Structure.

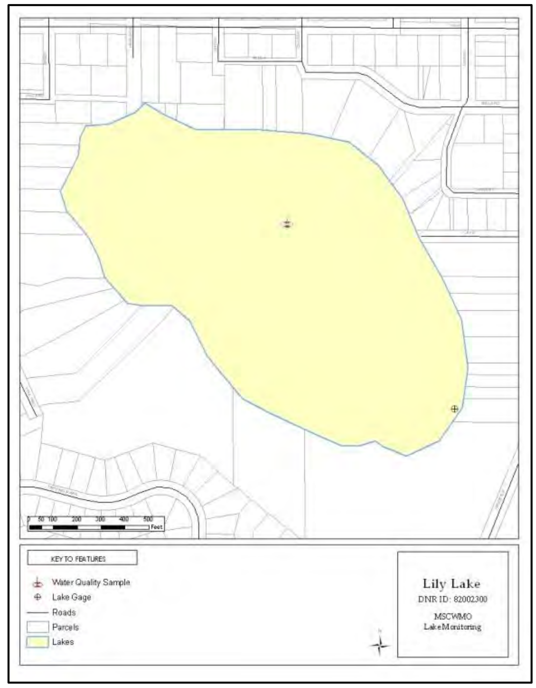
Perro Creek results indicate that a source may be contributing may *E. coli* to the creek somewhere in the City of Bayport. In 2016 results did not increase between Perro Creek at the Perro Pond Outlet to Perro Creek at the Diversion Structure, as typically expected when moving downstream. In 2017 half of the *E. coli* results decreased from Perro Creek at 6th Street to Perro Creek at the Diversion Structure, despite the Diversion Structure being downstream from 6th Street. This indicates that a source of groundwater may be contributing to Perro Creek between these two locations and diluting *E. coli*. During a few site visits the WCD staff noticed dry conditions at Perro Creek at the Perro Pond Outlet and Perro Creek at 6th Street while water was flowing at Perro Creek at the Diversion Structure. The variance between 2016 and 2017 results will guide further monitoring in 2018 to investigate and determine the source of *E. coli* entering Perro Creek. In addition to the current sampling sites, seven new sites will be established to collected *E. coli* samples along the creek in the City of Bayport.

APPENDIX A
WATER QUALITY DATA – LILY LAKE AND MCKUSICK LAKE

LILY LAKE

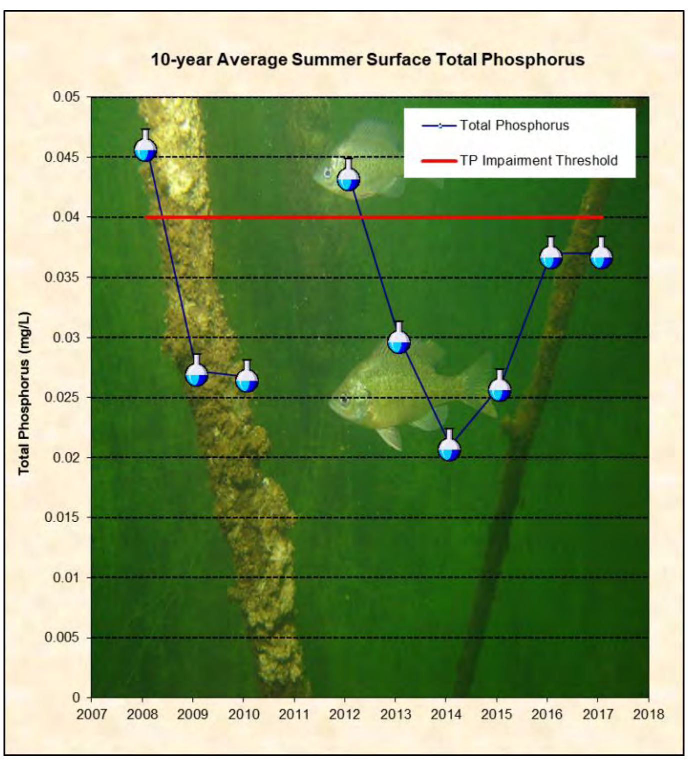
2017 Lake Grade C+

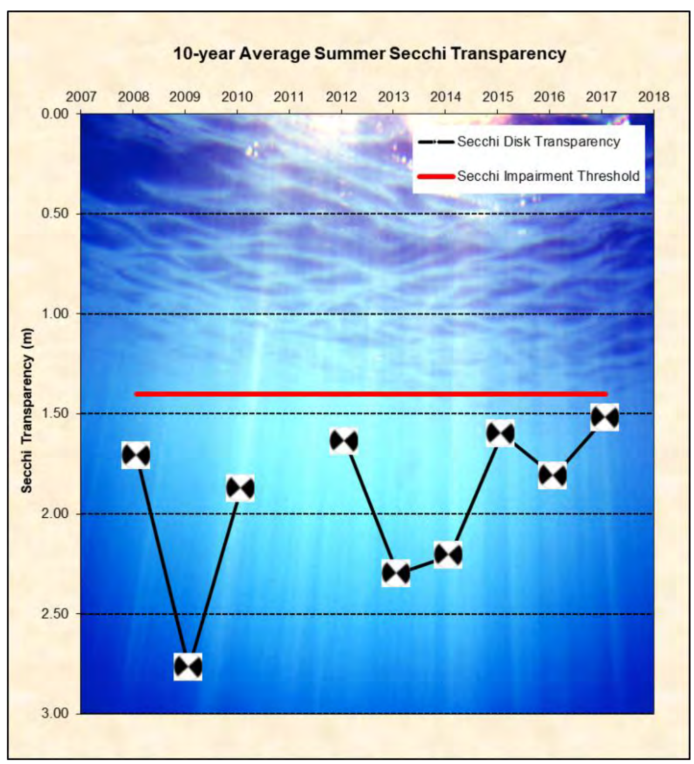
- DNR ID #: 820023
- Municipality: City of Stillwater
- Location: NE ¼ Section 32, T30N-R20W
- Lake Size: 35.90 Acres
- Maximum Depth (2017): 47.0 ft
- Ordinary High Water Mark: 844.8 ft
- 55%Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.
- Publically accessible



Summary Points

- Based on the chlorophyll-α results Lily Lake was considered eutrophic in 2017, according to the Carlson Trophic State Index.
- Using a Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average total phosphorus and no trend is present for average Secchi transparency or average chlorophyll-α corrected for pheophytin.
- The major land use is urban/residential.
- The lake stratified in 2017 with the thermocline around 4 meters deep.
- Lily Lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





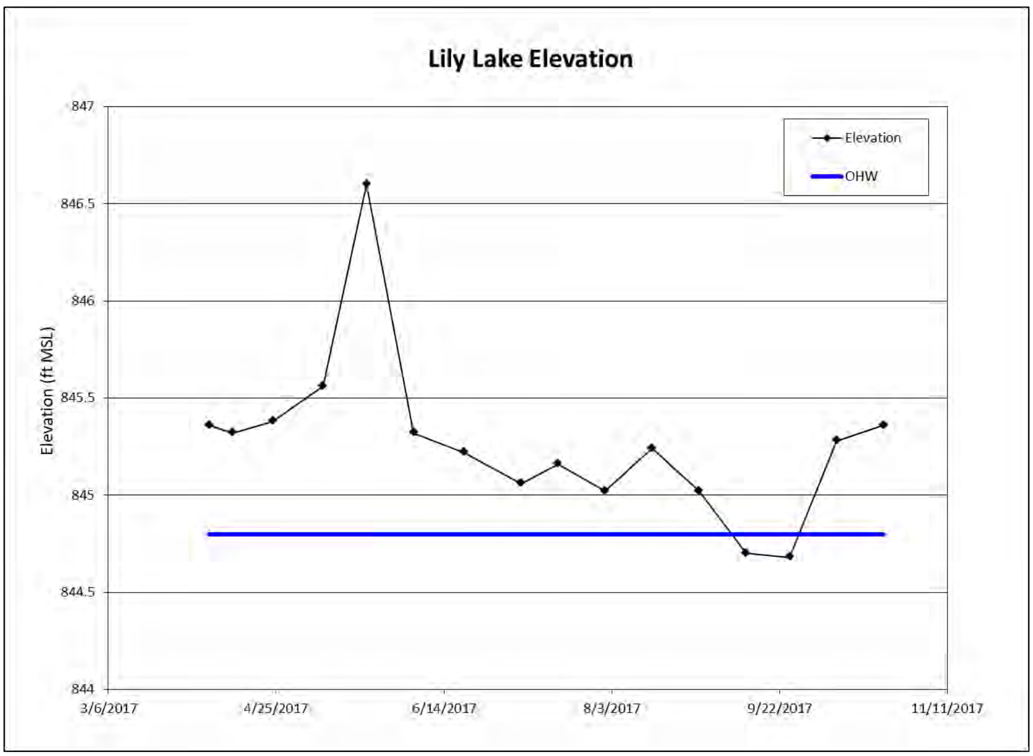
Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/13/2017 8:37	0.028	27.0	26.0	1.30	1.68	13.2	12.60
4/24/2017 12:05	0.042	7.9	7.5	0.86	1.83	14.8	11.75
5/9/2017 7:53	0.028	5.8	5.1	0.82	2.90	15.8	9.86
5/22/2017 13:23	0.028	2.5	1.9	0.74	3.05	15.2	6.91
6/6/2017 7:57	0.022	2.7	2.3	0.66	3.05	22.6	8.67
6/20/2017 12:04	0.030	7.8	7.0	0.95	2.13	23.6	7.79
7/5/2017 11:42	0.061	17.0	17.0	0.95	1.37	25.9	9.72
7/18/2017 11:31	0.030	19.0	17.0	0.93	1.22	26.7	7.73
8/1/2017 11:43	0.035	33.0	32.0	1.20	0.61	28.2	12.93
8/15/2017 12:07	0.043	18.0	16.0	1.30	1.07	23.1	5.05
8/29/2017 11:43	0.036	14.0	12.0	0.93	1.37	21.9	7.18
9/12/2017 11:25	0.036	18.0	23.0	0.95	1.68	20.9	9.25
9/26/2017 11:39	0.040	42.0	40.0	1.10	1.22	21.8	8.73
10/9/17 11:25	0.034	31.0	30.0	1.10	1.22	16.4	6.83
2017 Average	0.035	17.6	16.9	0.99	1.74	20.7	8.93
2017 Summer Average	0.037	19.1	18.5	1.00	1.52	23.9	8.56

Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*

Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*

	High	High Date	Low	Low Date	Average
2017 Elevation (ft)	846.60	5/22/2017	844.68	9/25/2017	845.27

*Data requirements and determinations of use assessment according to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters: "Samples must be collected over a minimum of 2 years and data used for assessments must be collected from June to September. Typically, a minimum of 8 individual data points for TP, corrected chlorophyll-a (chl-a corrected for pheophytin), and Secchi are required. Data used for phosphorus and chlorophyll-a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine summer-mean values for TP, corrected chl-a, and Secchi depth. These values are then compared to the standards and the assessment is made."



Lake Water Quality Summary

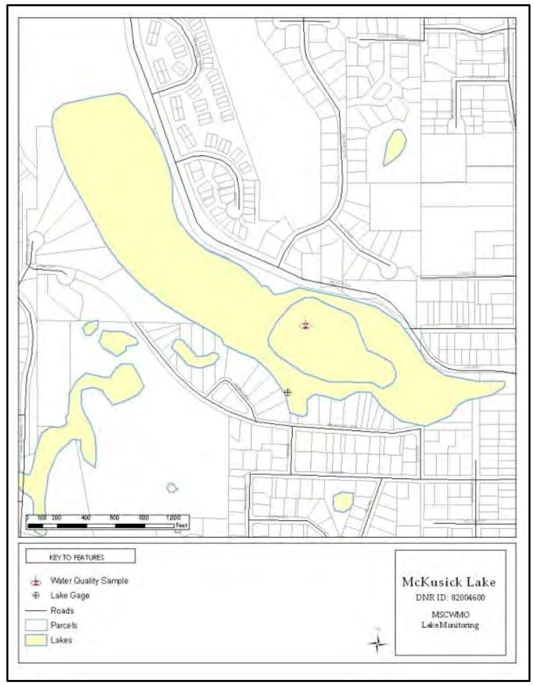
	Summertime Lake Grades									
	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Total Phosphorus (mg/L)	C	C	B	A	B	C	NA	B	B	C
Chlorophyll-*a* (ug/L)	B	C	C	B	B	B	NA	C	A	C
Secchi depth (ft)	C	B	C	B	B	C	NA	C	B	C
Overall	**C+**	**C+**	**C+**	**B+**	**B**	**C+**	**NA**	**C+**	**B+**	**C**

MCKUSICK LAKE

2017 Lake Grade C+

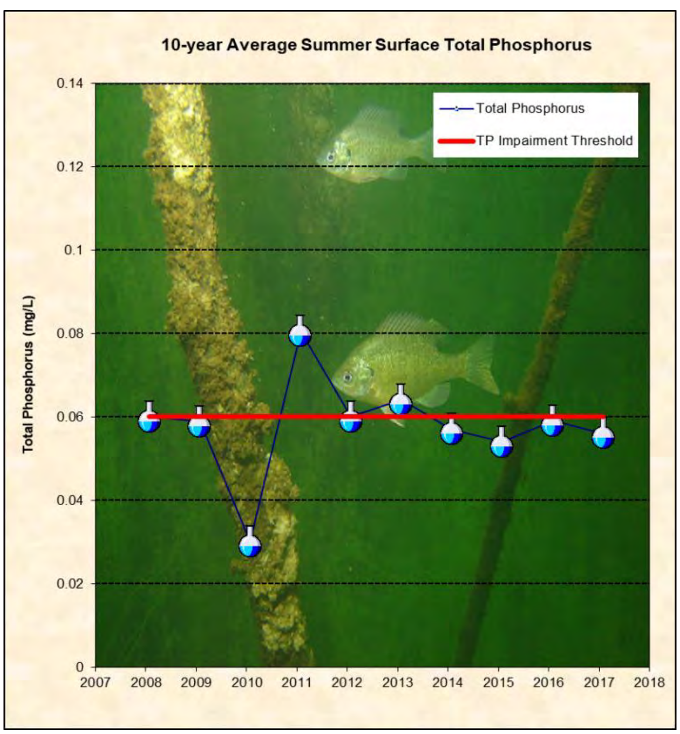
DNR ID #: 820020

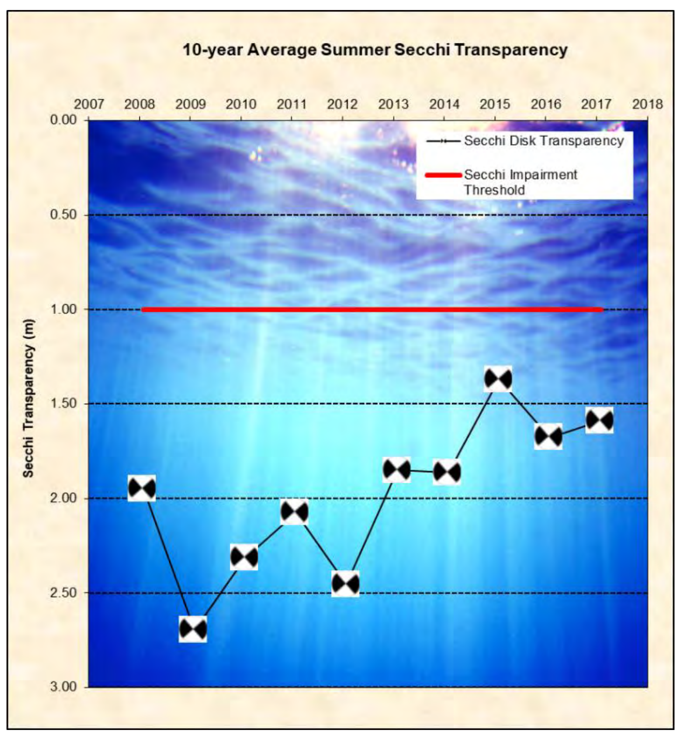
- Municipality: City of Stillwater
- Location: NE ¼ Section 29, T30N-R20W
- Lake Size: 46 Acres
- Maximum Depth (2017): 14 ft
- Ordinary High Water Mark: 851.7 ft
- 100% Littoral
  Note: Littoral area is the portion of the lake <15 ft and dominated by aquatic vegetation.



Summary Points

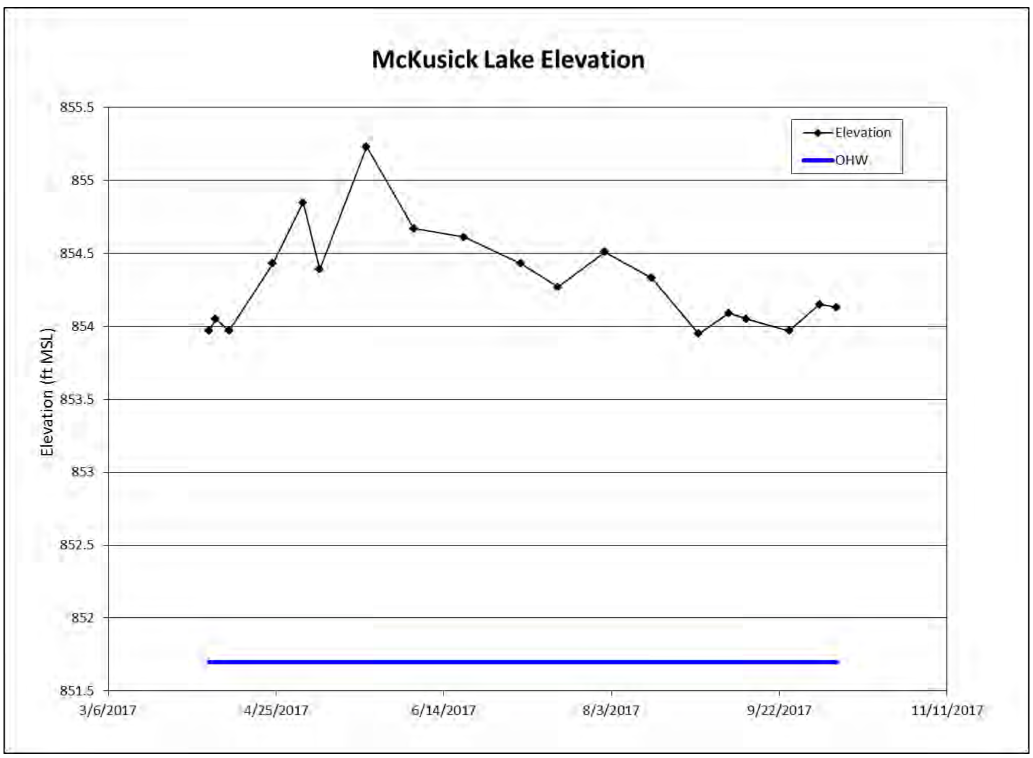
- Based on the chlorophyll-α results McKusick Lake was considered eutrophic in 2017, according to the Carlson Trophic State Index.
- Using a Kendall's Tau correlation test ($p<0.05$) there is a statistically significant **improving** trend for average Secchi transparency and average total phosphorus, but there is no trend for average chlorophyll-α corrected for pheophytin.
- The major land use is urban/residential.
- The lake stratified in 2017 with the thermocline around 3 meters deep.
- McKusick Lake was delisted in 2012 for its impairment for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List.





Date/Time	Total Phosphorus (mg/L)	Uncorrected Trichromatic Chlorophyll-*a* (ug/L)	Pheophytin-Corrected Chlorophyll-*a* (ug/L)	Total Kjeldahl Nitrogen (mg/L)	Secchi Disk Depth (m)	Surface Temperature (Celsius)	Surface Dissolved Oxygen (mg/L)
4/11/2017 14:52	0.039	6.7	5.4	0.64	1.83	11.5	10.40
4/24/2017 13:21	0.023	2.9	2.5	0.58	2.29	15.4	11.79
5/8/2017 13:46	0.015	2.3	1.4	0.44	2.59	16.0	11.90
5/22/2017 13:57	0.040	2.2	1.9	0.64	1.98	14.1	6.42
6/6/2017 8:31	0.021	1.8	1.8	0.66	2.59	21.8	9.49
6/20/2017 11:31	0.047	5.2	3.8	0.86	1.37	22.0	3.03
7/5/2017 11:14	0.075	8.0	7.3	0.81	1.37	25.1	5.67
7/18/2017 11:05	0.098	28.0	24.0	1.30	1.22	25.3	4.07
8/1/2017 11:18	0.093	28.0	25.0	1.30	0.91	25.6	1.63
8/15/2017 11:12	0.054	14.0	11.0	0.88	0.91	21.1	1.01
8/29/2017 11:14	0.029	7.4	6.8	0.66	1.68	20.4	2.98
9/12/2017 10:55	0.038	7.5	6.5	0.74	2.13	19.8	6.56
9/25/2017 13:23	0.049	12.0	11.0	0.78	2.13	22.4	5.37
10/9/17 10:54	0.043	14.0	12.0	0.81	2.29	15.4	4.51
2017 Average	0.047	10.0	8.6	0.79	1.81	19.7	6.06
2017 Summer Average	0.056	12.4	10.8	0.89	1.59	22.6	4.42
Water quality thresholds are 0.04 mg/L TP, 14 µg/L CL-a, 1.4 m Secchi depth*							
Shallow lake water quality thresholds are 0.06 mg/L TP, 20 µg/L CL-a, 1.0 m Secchi depth*							
	High	**High Date**	**Low**	**Low Date**	**Average**		
2017 Elevation (ft)	855.23	5/22/2017	853.95	8/29/2017	854.32		

*Data requirements and determinations of use assessment according to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters: "Samples must be collected over a minimum of 2 years and data used for assessments must be collected from June to September. Typically, a minimum of 8 individual data points for TP, corrected chlorophyll-a (chl-a corrected for pheophytin), and Secchi are required. Data used for phosphorus and chlorophyll-a calculations are limited to those collected from the upper most 3 meters of the water column (surface). If more than one sample is collected in a lake per day, these values are averaged to yield a daily average value. Following this step, all June to September data for the 10-year assessment window are averaged to determine summer-mean values for TP, corrected chl-a, and Secchi depth. These values are then compared to the standards and the assessment is made."



Lake Water Quality Summary										
	Summertime Lake Grades									
	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Total Phosphorus (mg/L)	C	C	C	C	C	C	D	B	C	C
Chlorophyll-*a* (ug/L)	B	B	C	C	B	A	C	A	A	B
Secchi depth (ft)	C	C	C	C	C	B	C	B	B	C
Overall	**C+**	**C+**	**C**	**C**	**C+**	**B**	**C-**	**B+**	**B**	**C+**